NASA/GSFC Testing of Li-Ion Cells: Update

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Objective

- Temperature
- Charge voltage
- Number of cycles under LEO regime
- Determination of Cycling Performance as a Battery Pack
- Mid-discharge voltage
- Self-discharge
- Capacity
- Cell Characterization

NASA

Lockheed Martin
Cells Under Study

- 8 AH Lithium Technology, Inc.
- 3 AH Alliant Tech.
- Polymer cells
- 12 AH, 4 AH and 1.25 AH SAFI
- Cylindrical Cells
- 1.5 AH Wilson Creatchatch
- 20 AH Yardney
- Prismatic Cells
- WG - 25%
- ATK - 2%
- SAEF - 0.9%
- Yardeny - 2%

C/2 from C/5

Capacity Decrease when the discharge rate is increased to

- Wilson Greathatch (WG) = 1.4%
- Alliant Tech (ATK) = 2%
- SAEF = 1.4%
- Yardeny = 1.4%

Self-discharge - 72 hours charged open-circuit stand

Characterization Data
Characterization Data - Cont'd.

- $\text{MC} = 68$
- $\text{ATK} = 51$
- $\text{Xadney} = 10.2$
- $\text{SAFT} = 1.74$

Cell Impedance (mohms) at 50% SOC

- $\text{MC} = 3.65V$
- $\text{ATK} = 3.54V$
- $\text{SAFT} = 3.56V$
- $\text{Xadney} = 3.51V$

Mid-discharge voltages at C/2 discharge rate
- AVK = 51%
- W6 = 91%
- SAEF = 91%
- Yardney = 92%

Capacity at 0°C in percentage of capacity at 25°C

Characterization Data - Cont'd
LEO Cycling: Conditions

- Recharge rate = 1.01
- Rate with current taper
- Charge voltage clamped at a Battery/Pack voltage at C/2
- Depth of discharge = 40%
- Temperature = -20°C to 40°C
- Continuous cycling in a regime consisting of 16 cycles/day discharge and 60 min. charge at the rate of 16 cycles/day

Charge voltage clamped at a Battery/Pack voltage at C/2
<table>
<thead>
<tr>
<th>STATUS</th>
<th>NUMBER</th>
<th>Cycles</th>
<th>Charge</th>
<th>CAP, AH</th>
<th>Number of Cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEO Cyclic: Data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Cells 192, 194, 195 and 196 have previously completed 2966 cycles. *
Cycling for WEC cells at 20°C, 41 V limit
Variation of EOD voltage with cycle number.
NUMBER OF CYCLES

EOD VOLTS

CELL AT 30°C, 3.85V LIMIT

VARIATION OF EOD WITH CYCLING FOR SAFETY 1.25 AH
<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>Number of cycles</th>
<th>End of dischg voltage</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>10</td>
<td>-10</td>
<td>cell charged to 3.85V</td>
</tr>
<tr>
<td></td>
<td>-20</td>
<td>39</td>
<td>cell charged to 4.1V</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>2</td>
<td>cell charged to 4.48V</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>0</td>
<td>cell charged to 4.1V</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>560</td>
<td>cell charged to 3.85V</td>
</tr>
<tr>
<td></td>
<td>4289</td>
<td>3.217</td>
<td></td>
</tr>
<tr>
<td>6157</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Voltage Behavior During Cycling for SAFI

20°C, 3.85 V Limit

4 Ah Cells

EOO VOLTAGE

Cycle Number

000 0000 0000 0000 0000 0000 3000 0000

VOLTAGE
By monitoring and managing the cell parameters and conditions, the data suggests the potential use of a battery level charge meter.

The solid electrolyte and gel electrolyte cells' performance is inferior to the liquid electrolyte cells under our LEO test conditions.

Limited cycling excursion to minus 20°C (low temperatures) does not appear to impair the cycling behavior at 20°C.

Limited cycling excursion excursion to minus 10°C unless the voltage limit on charge is increased to 4.5V.

Cells cannot be cycled in a 90-minute orbit and 40% DOD at minus 10°C unless the voltage limit on charge is increased to 4.5V.

Charge acceptance of the cells decreases with temperature.

N/H² Batteries charged open-circuit stand test that is superior to Nichad and charged self-discharge rate of Li-ion cells is 1.4% in the 72-hr.

Conclusions